Take Full Advantage of LDPC Soft Bit Decoding

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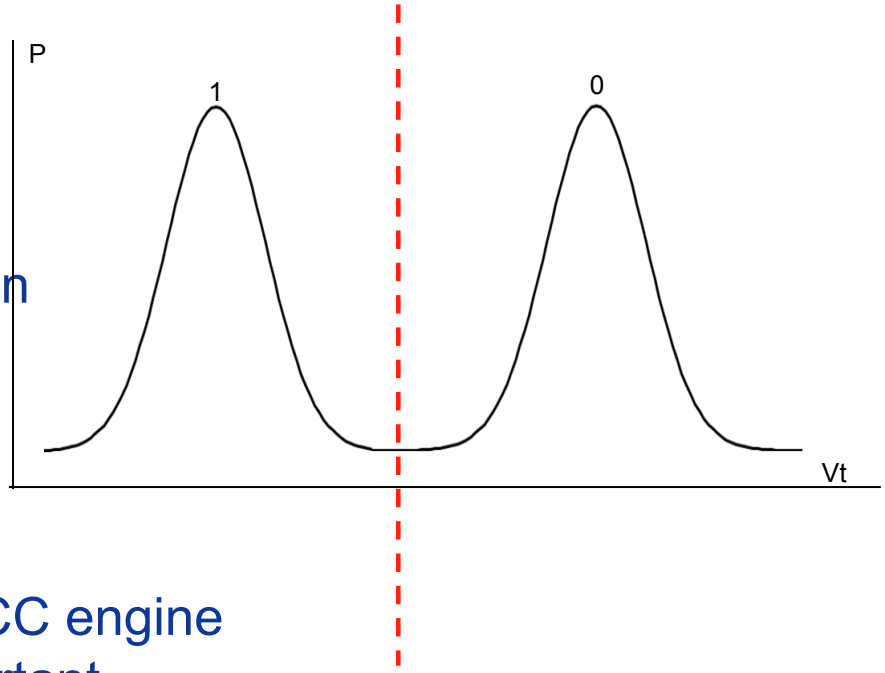
Starblaze Technology

Flash Memory Summit

NAND Flash is changing

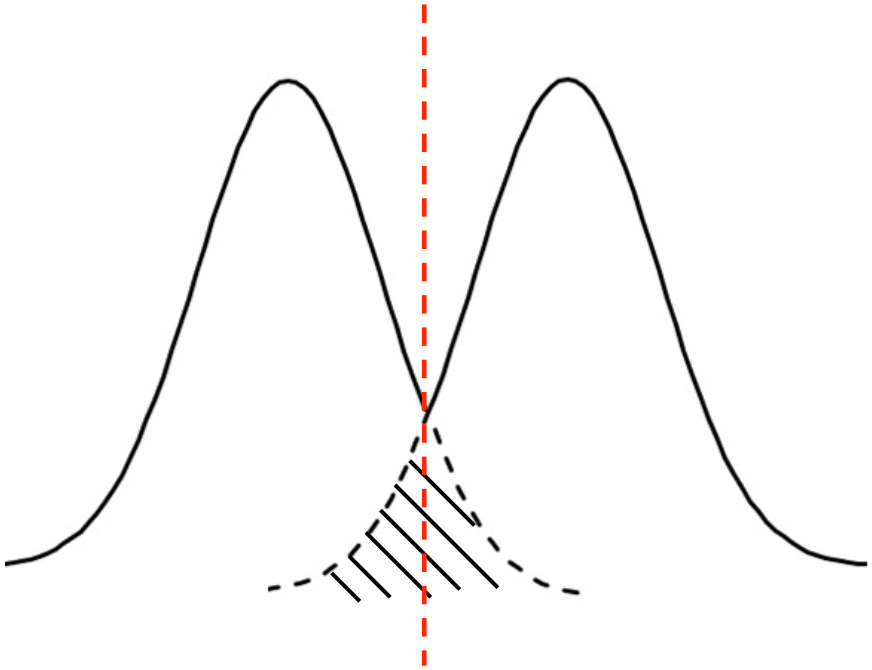
- Flash evolution
  - 2D -> 3D
  - MLC -> TLC/QLC
- Factors aggravate the distribution
  - PE cycles
  - Retention
  - Disturb
  - …



- ➢ Flash vender needs powerful ECC engine
- ➢ Soft decoding will be more important

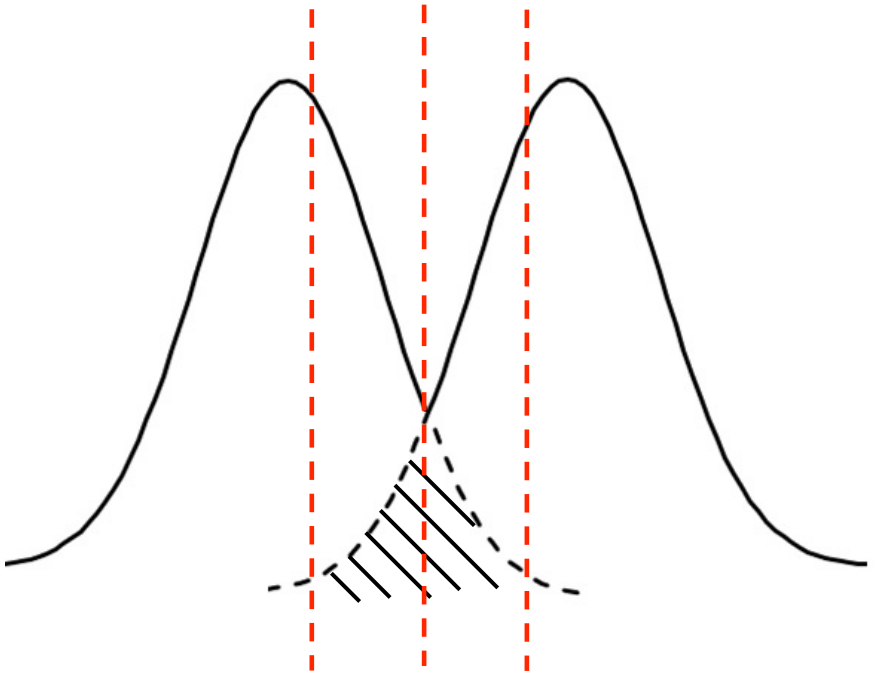
Soft decoding is powerful

- Shadow area decides the raw bit error rate with best Vt
- Vt shift read can not promise successful hard decode when raw bit error rate is high
- LDPC advantage
  - Hard decoding have slightly better capability compared with BCH
  - Long codeword size promises better capability
  - Soft decoding guarantees EOL data integrity
- Retry/Vt shift read is preferred, but soft decoding is the last straw



What matters

- Soft bit read strategy
  - Number of reads
  - Offset of reads
- LLR mapping strategy
  - 00/01/10/11 will be map to?
- Soft bit decode algorithm
  - Algorithm
  - Quantity
  - Max iteration

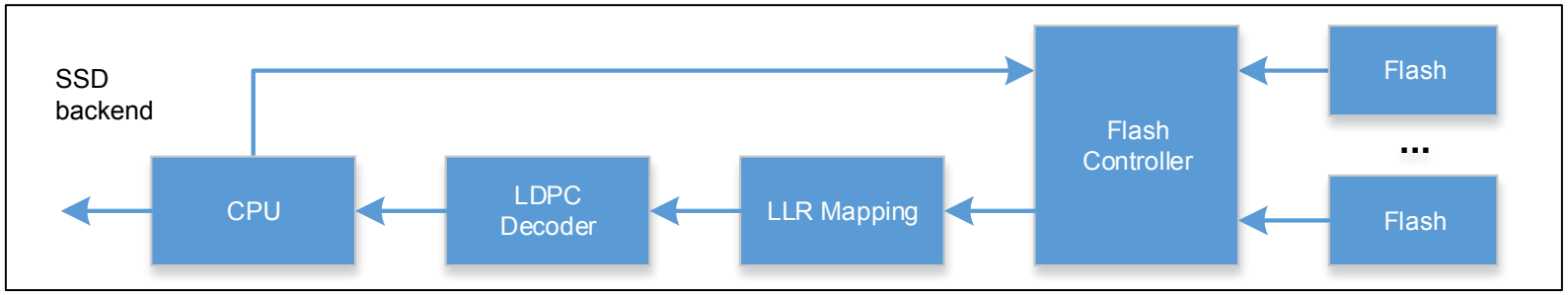


When

- Some recovery method Before soft way:
  - Vender provided read retry
  - Customized Vt shift read
  - Self adjustment read (start point/step/count)
  - Offline machine learning read
  - …
- Then Soft Way!
  - Hard decode first, too much information can be used in soft sensing, LLR map and soft decode algorithm

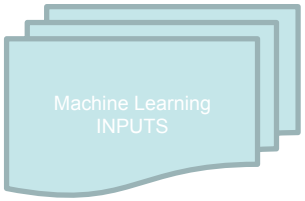
Dynamic lite machine learning

- Hard decode information can be collected by CPU, both successful and fail frames
- CPU will do machine learning based on selected hard decode information and decide what to do next



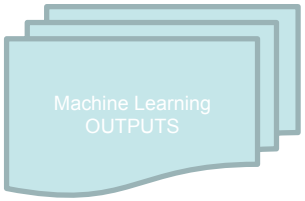
Dynamic lite machine learning

- What we have before hard decode?
  - PE cycle
  - Retention times
  - Page address
  - …
- What we have after hard decode?
  - Hard bit Vt
  - Syndrome weight of each iteration
  - Number of flipped bits in the hard decode
  - Number of “1” in the hard sensing
  - Read cost time
  - Hard read difference of previous read with different Vt
  - Calibrated retention times



Dynamic lite machine learning

- Soft read is must or not
  - DLML decides if hard decoding with other Vt is enough
- Re read hard bit or not
  - BER of previous hard read is high
- One more or two more or even more reads
- LLR corresponding to soft read
- Any adjustment to soft decode algorithm
  - Normalize factors
  - Max iteration
- Soft decode maybe not work, go for RAID



Performance

- Hard decode + vender retry + tradition soft
- Hard decode + optimal Vt read + tradition soft
- Hard decode + optimal Vt read + DLML soft

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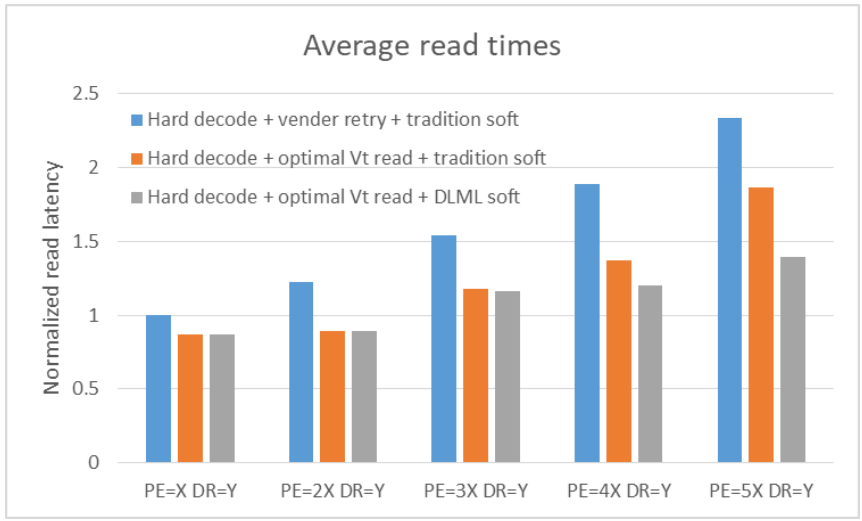
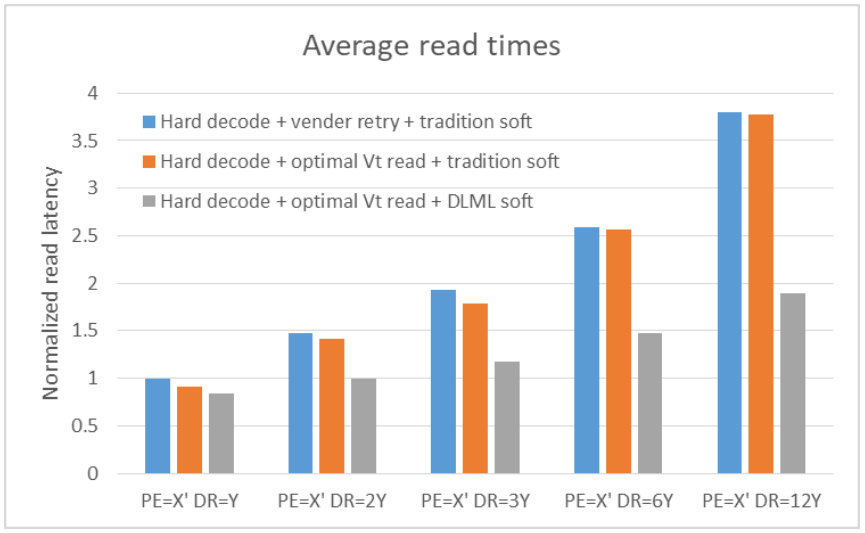
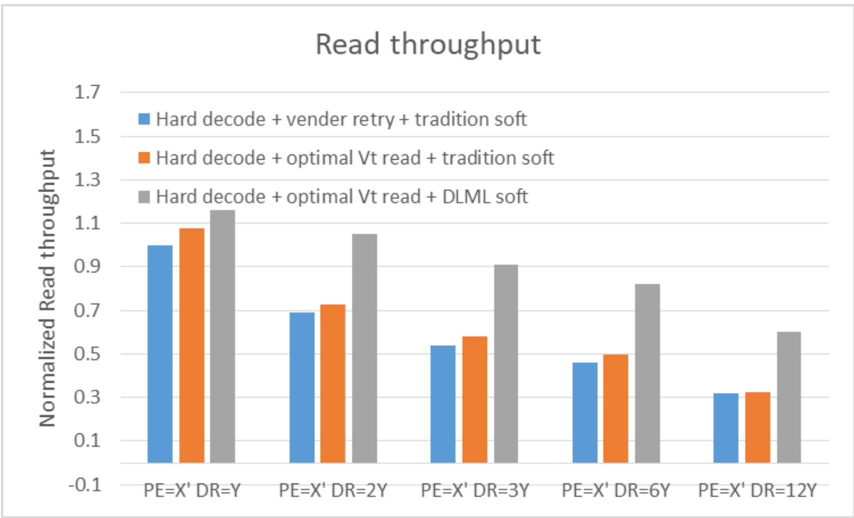
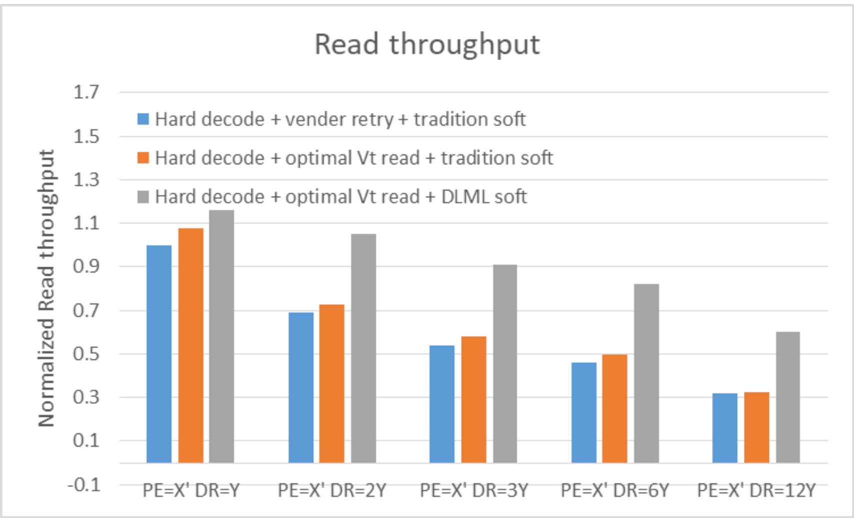
Average read latency





Read throughput





Conclusion

- Soft bit is powerful but hard to use
- Offline machine learning use limited information, improved the soft decoding accurate rate
- Online lite machine learning make it works in more efficiency way.

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